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(54) Abstract Title
Robotic floor cleaning device

(57) A robotic floor cleaning device comprising power operated means 20, 21 for moving the cleaning device along the floor, at least one rechargeable battery 13, 14, a navigation system for navigating the cleaning device around the room and a power management system 18 for distributing power from the rechargeable battery to the power operated means and to the navigation system, the power management system and the navigation system each having its own separate processing system 23, 33.

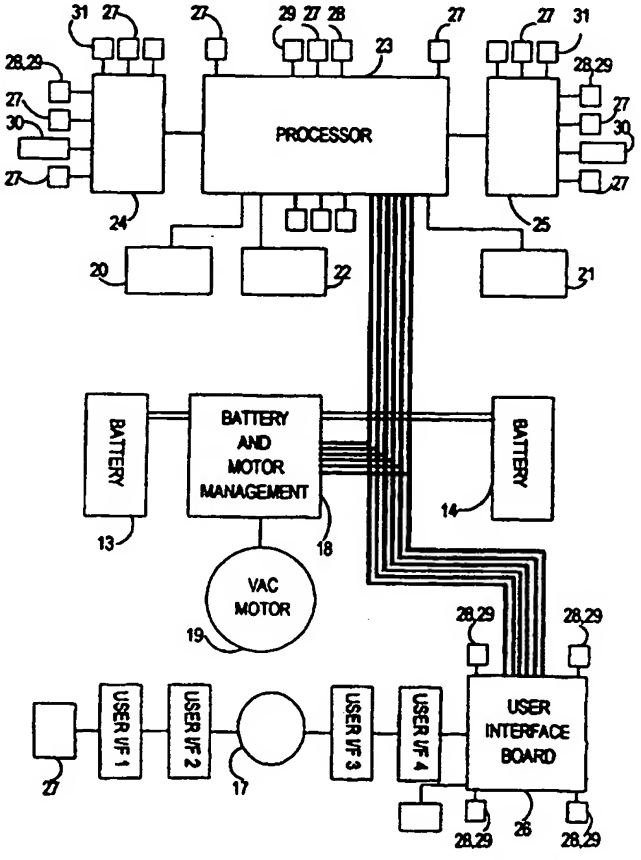

FIG 2

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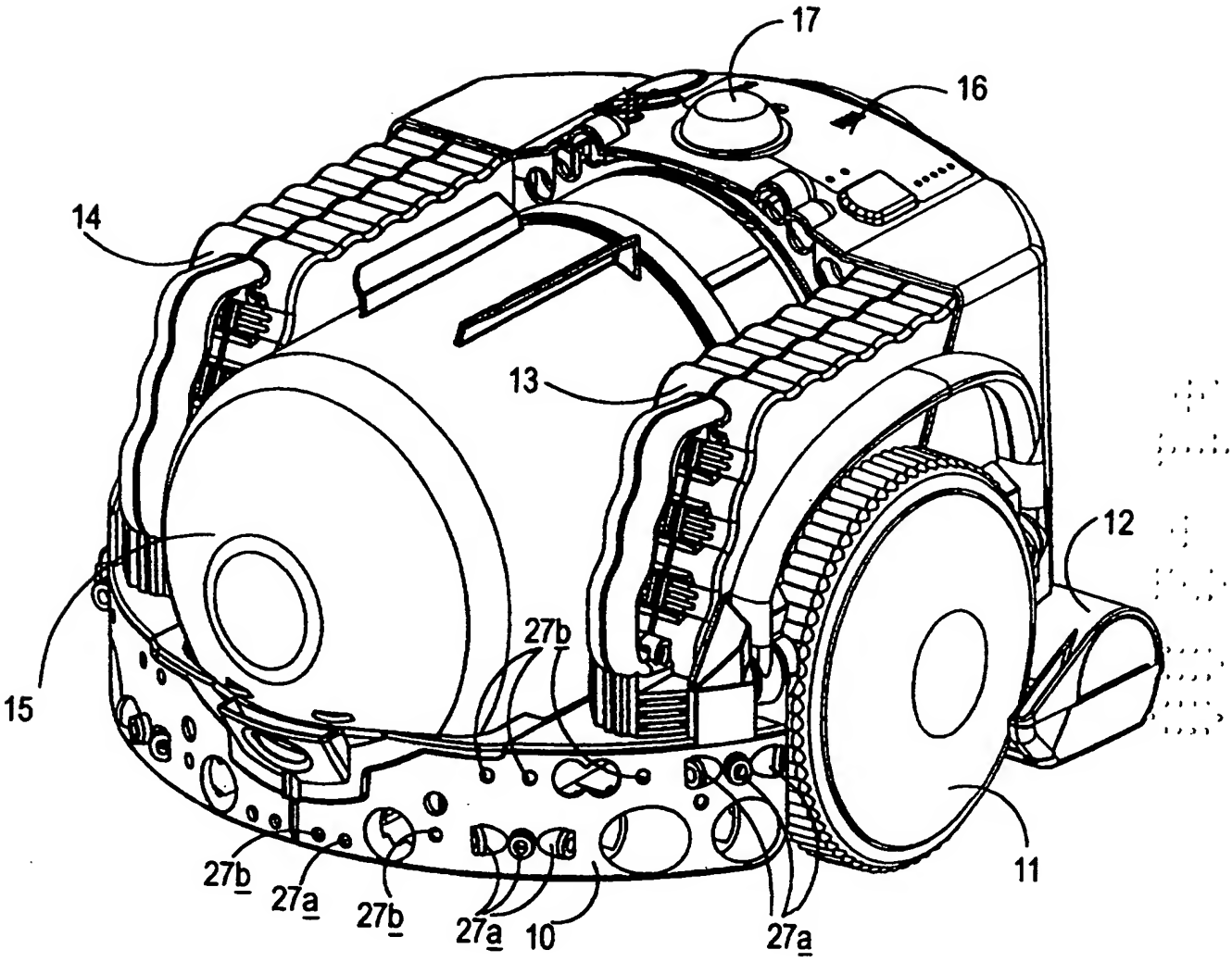
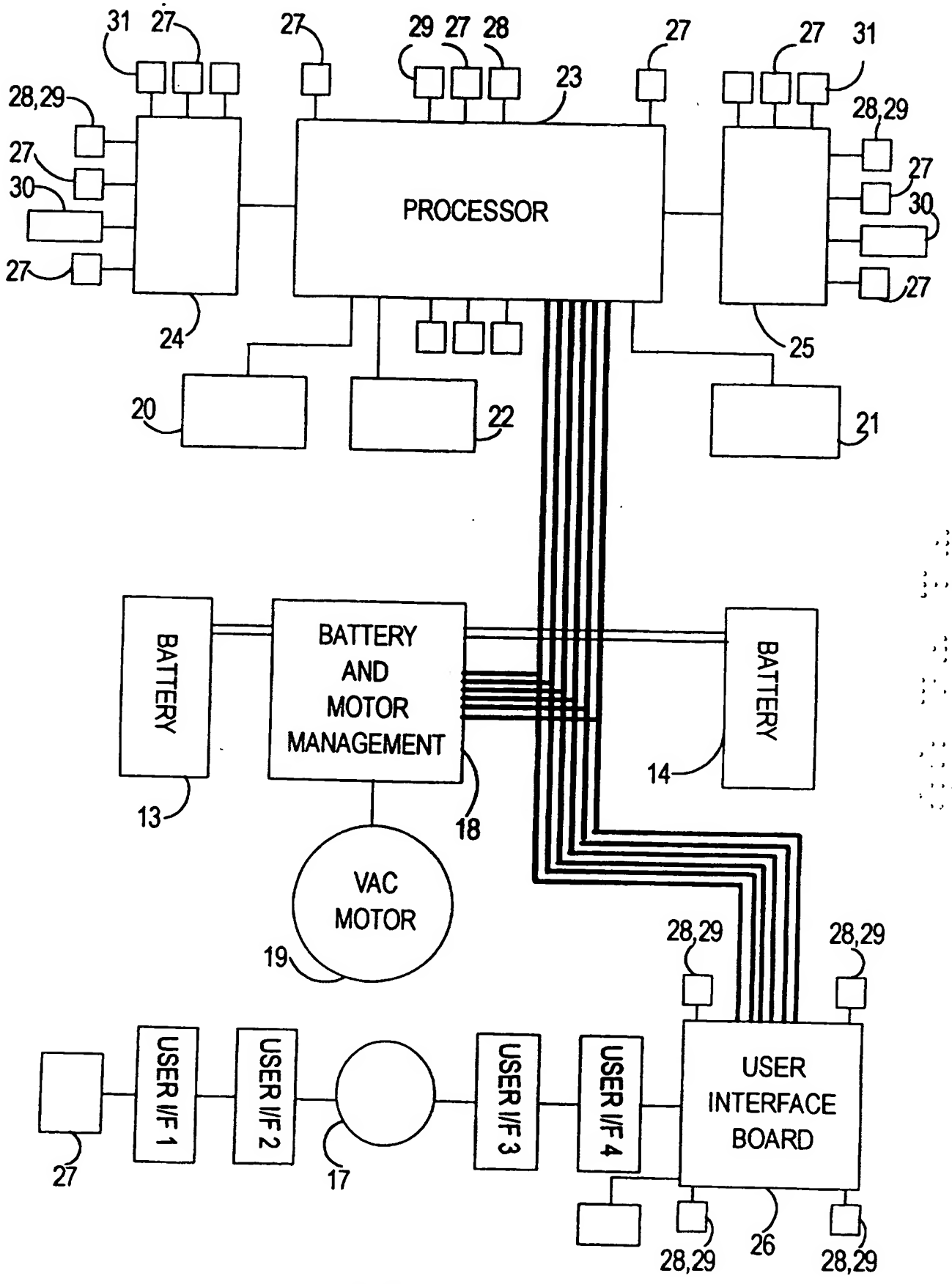


FIG.1.


31
27
27
29
27
28
27
27
31
28,29
23
28,29
27
30
PROCESSOR
27
30
27
27
24
25
20
22
21
BATTERY
BATTERY AND MOTOR MANAGEMENT
BATTERY
13
18
14
VAC MOTOR
19
28,29
28,29
USER I/F 1
USER I/F 2
USER I/F 3
USER I/F 4
USER INTERFACE BOARD
27
17
28,29
26
28,29

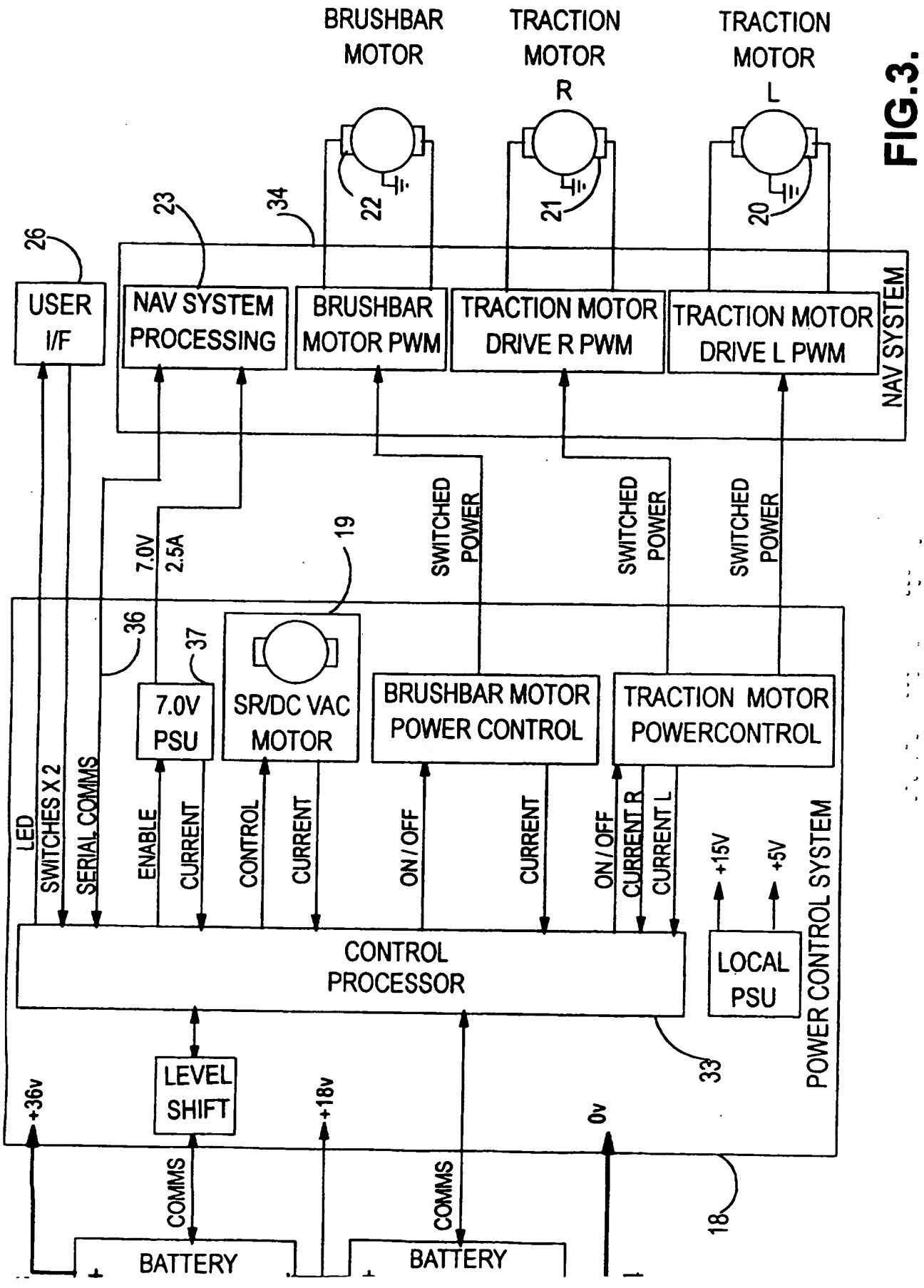

BRUSHBAR MOTOR
TRACTION MOTOR R
TRACTION MOTOR L
22
21
20
23
34
26
USER I/F
NAV SYSTEM PROCESSING
BRUSHBAR MOTOR PWM
TRACTION MOTOR DRIVE R PWM
TRACTION MOTOR DRIVE L PWM
NAV SYSTEM
7.0V
2.5A
19
SWITCHED POWER
SWITCHED POWER
SWITCHED POWER
36
37
7.0V PSU
SR/DC VAC MOTOR
BRUSHBAR MOTOR POWER CONTROL
TRACTION MOTOR POWERCONTROL
LED
SWITCHES X 2
SERIAL COMMS
ENABLE
CURRENT
CONTROL
CURRENT
ON / OFF
CURRENT
ON / OFF
CURRENT R
CURRENT L
+15V
+5V
CONTROL PROCESSOR
LOCAL PSU
POWER CONTROL SYSTEM
33
LEVEL SHIFT
+36v
+18v
0v
COMMS
COMMS
18
BATTERY
BATTERY

FIG.3.

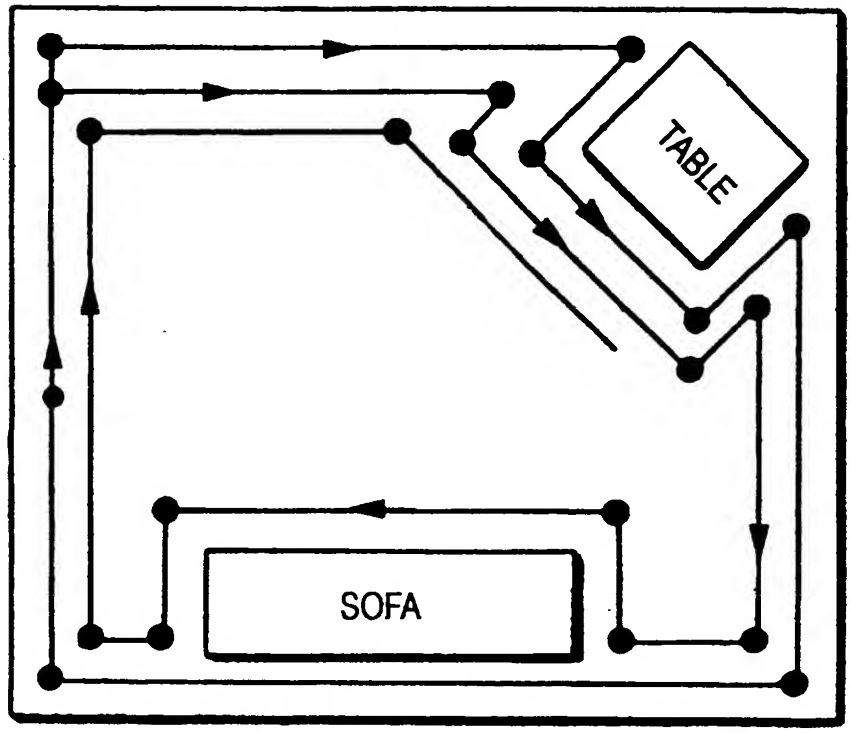


FIG.4.

IMPROVEMENTS IN OR RELATING TO FLOOR CLEANING DEVICES

This invention relates to floor cleaning devices, and more particularly to robotic floor cleaning devices such as robotic vacuum cleaners.

According to the invention there is provided a robotic floor cleaning device comprising power operated means for moving the cleaning device along the floor, at least one rechargeable battery, a navigation system for navigating the cleaning device around the room and a power management system for distributing power from the rechargeable battery to the power operated means and to the navigation system, the power management system and the navigation system each having its own separate processing system.

The provision of two separate processing systems will allow each system to carry out an integrity check on the other processor and to shut down the cleaning device if a fault is detected.

Preferred and/or optional features of the invention are set forth in claims 2 to 10, inclusive.

The invention will now be more particularly described, by way of example, with reference to the accompanying drawings in which:-

Figure 1 is a perspective view of one embodiment of a robotic floor cleaning device, according to the invention,

Figure 2 is a block circuit diagram of the power management system and the navigation system of the robotic floor cleaning device shown in Figure 1,

Figure 3 is a more detailed block circuit diagram of the power management system shown in Figure 2, and

Figure 4 is a schematic view illustrating one method of operating the robotic floor cleaning device.

Referring firstly to Figure 1 of the drawings, there is shown therein a robotic floor cleaning device in the form of a robotic vacuum cleaner comprising a main body 10, two drive wheels 11 (only one of which is shown), a brushbar housing 12, two rechargeable batteries 13 and 14, a dual cyclone 15 of the type described in EP-A-0042723, a user interface 16, one (or more) light detectors 17 and various sensors 27 to 31 which will be more particularly described hereinafter. The light detector 17 detects light received from a plurality of compass points around the vacuum cleaner and is more particularly described in our co-pending British Patent Application No. [our reference GBP0099] of even date.

The circuit shown in Figure 2 comprises the two rechargeable batteries 13 and 14, a battery and motor management system 18, a motor 19 for driving a suction

fan, motors 20 and 21 for driving the left and right hand wheels 11 of the vacuum cleaner, a motor 22 for driving a brushbar of the vacuum cleaner, processing circuitry 23 (which includes a microprocessor and field programmable gate arrays) for a navigation system 34 (see Figure 4), left and right hand sensor interfaces 24 and 25, respectively, a user interface board 26 and the light detector 17.

The navigation system of the robotic vacuum cleaner also includes a plurality of infra-red transmitters 27a and infra-red receivers 27b, a plurality of ultrasonic transmitters 28 and ultrasonic receivers 29, threshold detectors 30 for detecting the presence of a portable threshold locator 32 placed, for example, at the entrance to a room or at the top of a staircase and one or more pyroelectric detectors 31 for detecting animals and fires. There are four main ultrasonic receivers 29 which face forwards, rearwards and to opposite sides of the robotic vacuum cleaner. The signals received from these receivers not only provide information representative of distance from a feature of the room or from an object in the room but the amplitude and width of the received signals vary according to the type of material sensed.

As shown in Figure 3, the battery and motor management system 18 comprises a central processor 33 which receives data from battery monitors (not shown) in the rechargeable batteries 13 and 14. The processor 33 calculates the remaining charge in the batteries 13 and 14 and passes this information on to the processing circuitry 23 of the navigation system 34.

The central processor 33, typically a Hitachi H8/3334 F microprocessor, is

connected to the user interface board 26 and supplies power to the navigation system 34 which includes the processing circuitry 23 and sensors 27 to 31. It also supplies power to the motors 19, 20, 21 and 22.

A global ON/OFF switch 35 is located on the user interface 16. The switch 35 interacts directly with the processor 33. Setting the switch 35 to OFF initiates a power down sequence which ultimately sets the processor 33 into a "sleep" state. Setting the switch 35 to ON "wakes" the processor 33 which then executes a power up sequence.

Communication lines 36 between the processor 33 and the navigation system 34 carry data relating to the batteries 13 and 14 and the motor 19 in one direction, and a drive command for the motors 19, 20, 21 and 22 in the other direction.

The battery and motor management system 18 includes a power supply unit 37 for providing a regulated 7 volt supply to the navigation system 34. The power supply unit 37 and the motors 19, 20, 21 and 22 have current sensors (not shown) and these allow the processor 33 to monitor the current taken by the power supply unit 37 and the motors 19, 20, 21 and 22 and to shut down the vacuum cleaner if a predefined limit is exceeded. Information relating to the current taken by the motors 20 and 21 also provides an indication of the gradient and type of surface over which the vacuum cleaner is moving. The outputs from the current sensors are analogue signals. These are conditioned and then converted to digital values for subsequent processing by analogue-to-digital converters integrated into the processor 33.

The traction and brushbar motors 20, 21 and 22 (and possibly the suction fan motor 19) require pulse width modulation (PWM) speed control. The system therefore requires 3(4) PWM generators capable of providing 0-100% PWM at >50 kHz with a resolution of 1/128. The PWM control of the motors 20, 21 and 22 is carried out in the navigation system 34.

The provision of two separate processing system 23 and 33 allows each system to carry out an integrity on the other system and to shut down the vacuum cleaner if a fault is detected.

Figure 4 illustrates a method of operating the robotic vacuum cleaner. The cleaner is placed alongside a wall and energised to move forwardly along the edge of the room. The various sensors 27 to 31 will detect any portable threshold locators, obstacles in the room and other room features, such as corners of the room and fireplaces, and the processing circuitry 23 will navigate the robotic vacuum cleaner in order to avoid any such obstacles and to change direction when a corner of a room is reached. At each change of direction, the processing circuitry 23 will store information received from the light detector 17 and also from the four main ultrasonic receivers 29. It will also store information on the direction in which the cleaner turns at each change of direction. It will also constantly monitor the information received from the detector 17 and the four main receivers 29 and compare this with information previously stored. When the robotic vacuum cleaner reaches a position in which the information received from the light detector 17 and the four main receivers 29 is the same or substantially the same as

information previously stored, the processing circuitry 23 will determine that the robotic vacuum cleaner has completed a complete traverse around the room and is programmed to cause the robotic vacuum cleaner to step inwards by one cleaner width. The processing circuitry 23 will then be able to identify further changes of direction by comparing the information received from the light detector 17 and the four main receivers 29 with previously stored information and this will enable the robotic vacuum cleaner to navigate itself around the room avoiding any obstacles in its path in a generally inwardly spiral manner. The operating method is described in more detail in our co-pending Application No. [Our ref. GBP0100] of even date.

If the robotic vacuum cleaner is initially placed in the middle of the room, it will find a wall or obstacle. If it finds a wall it will follow the path described above. If it finds a feature (such as a central fireplace) or an obstacle in the centre of the room, it will complete a circuit around that feature or obstacle and then follow a generally outwardly spiral path.

CLAIMS

1. A robotic floor cleaning device comprising power operated means for moving the cleaning device along the floor, at least one rechargeable battery, a navigation system for navigating the cleaning device around a room and a power management system for distributing power from the rechargeable battery to the power operated means and to the navigation system, the power management system and the navigation system each having its own separate processing system.

2. A robotic cleaning device as claimed in claim 1, wherein the power management system monitors the current taken by the power operated means.

3. A robotic cleaning device as claimed in claim 2, wherein the power management system supplies information representative of the current taken by the power operated means to the navigation system as an indication of the gradient and type of surface over which the cleaning device is moving.

4. A robotic cleaning device as claimed in any one of claims 1 to 3, wherein the power management system includes a power supply unit for supplying a regulated voltage to the navigation system.

5. A robotic cleaning device as claimed in any one of the preceding claims, wherein the navigation system includes at least one light detector for detecting the level of light, memory means for storing information representative of the level of light each

time the cleaning device changes direction and means for comparing the level of light with previously stored information so that the cleaning device can identify when the level of light is the same or substantially the same as a level previously stored.

6. A robotic cleaning device as claimed in claim 5, wherein the or each light detector provides signals representative of the level of light received from a plurality of different compass points around the cleaning device.

7. A robotic cleaning device as claimed in any one of the preceding claims, wherein the navigation system includes a plurality of sensors for detecting obstacles.

8. A robotic cleaning device as claimed in any one of the preceding claims, wherein the power operated means comprise two ground engageable wheels and two electric motors for driving the two wheels, respectively.

9. A robotic cleaning device as claimed in any one of the preceding claims, the cleaning device being in the form of a vacuum cleaner including a suction device and a suction device motor for driving the suction device, the suction device motor being supplied with power by the power management system.

10. A robotic cleaning device as claimed in claim 9, further including a brushbar and brushbar motor for driving the brushbar, the brushbar motor being supplied with power by the power management system.

11. A robotic cleaning device substantially as hereinbefore described with reference to the accompanying drawings.

The Patent Office

10

INVESTOR IN PEOPLE

Application No: GB 9827761.9 **Examiner:** John Wilson
Claims searched: 1-11 **Date of search:** 18 March 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): A4F[FCCB FCCX]

Int Cl (Ed.6): A47L 9/28 11/40

Other: Online: WPI, EDOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	GB 2278937 A Samsung - has a single microproceesor.	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.